share of baccalaureates granted by all four-year institutions together. Alternatively, over one-fourth of the BA's in 1973-74 were in professional-technial fields (engineering, architecture, business, etc.). Less than 10 percent of liberal arts college graduates received degrees in these fields.

9. Eckhaus calculates internal rates of return under the assumption that direct costs are cancelled out by part-time earnings. If the conventional assumption holds (as well it might for 1960 when direct costs of tuition and books were low and financial aid funds were limited), then his "unadjusted" rates come closest to our social rates of return.

Faculty Working Papers

THE DEVELOPMENT OF A DISTRICT OFFICE PERFORMANCE MODEL FOR THE SOCIAL SECURITY ADMINISTRATION

John S. Chandler, Assistant Professor, Department of Accountancy

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Summary:

The Social Security Administration (SSA) operates District Offices with respect to four main performance goals: total elapsed client service time; operational effort level; workload volume; and cost. Unfortunately, these goals are not simultaneously achievable and necessitate design tradeoffs in order to attain satisfactory overall performance. To aid SSA management in making design decisions concerning people and processes in the District Office, a Multiple Goal Programming (MGP) model has been formulated which relates the operating behavior of a District Office to SSA performance goals. An idealized District Office is used to demonstrate the applicability of the MGP methodology to Social Security District Office planning. This example formulation is then solved via an MGP computer program. The results are interpreted with respect to their potential implications for SSA.

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1.0 INTRODUCTION

The interface between the citizen client and the Social Security Administration (SSA) is the District Office (DO). These offices provide such services as issuance of Social Security cards, payments of benefits and processing of claims. Each of these services is assigned a District Office Work Report (DOWR) number. For example, processing of Title XVI Disability Claims is identified as DOWR 10. There are 25 DOWR types in all.

The current DO employs a combination of human processing and technological (computerized) support to provide these services. The majority of processing is human, however. Each DOWR is characterized as a sequence of functions to be performed. An individual function in this sequence is identified as a Work Station. Typically, a Work Station corresponds to one or more desks and personnel who perform the associated function, i.e., the Work Station's resources. A given Work Station, however, may handle more than one, if not all, types of DOWR's that come to a District Office.

Social Security management use four criteria to plan and evaluate the operation of a District Office; two client oriented and two SSA oriented. Service to the client, is of prime importance. Although many factors affect this objective, a common quantitative factor is total system elapsed time to provide the client service. This is defined to be the period from the time the client initially requests a service at the District Office until the time that SSA has resolved the request for that service, e.g., payment of claim, issuance of the Social Security Card, etc. The second client related performance criterion is the volume of client requests (DOWR's) handled by a District Office in a given time period.

From a Social Security Administration point of view, the level of operational effort required to achieve a given level of client performance is important. This effort is a function of manpower level and degree of technological support (automation). Control over these elements can be aggregated at several levels. At the District Office level, budgets can be used to manage the number of personnel, degree of automation and costs of both. Within a District Office, usage can be monitored by the types of DOWR's or by the Work Station's functions. Below that level requirements can be analyzed by the type of personnel or type of technology employed. Each, and all, are valid control mechanisms over operational effort.

And finally, the cost of operating a District Office must be considered. Because Social Security Administration is a governmental body, the DO's are not profit oriented. Therefore, for evaluation purposes they can be treated as cost centers. Operational objectives are not only to keep actual costs in line with budgeted costs, but also to keep the current costs from rising, and, if possible, to reduce them. Costs can be measured by the following pools: a)by District Office, b) by DOWR , and c) by Work Station. The appropriate aggregation depends on the scope of control of the individual manager.

These individual goals, when applied to a District Office concurrently, form a complex evaluative environment. To support operations satisfying these criteria, there are many quantitative SSA constraints. For example, there is a maximum number of personnel available, a maximum elapsed time acceptable to clients and so on. It is not hard to envisage a situation where two or more objectives cannot be satisfied simultaneously, e.g, processing a larger volume of requests while reducing manpower. Thus, given the current man/machine system, the problem of assessing a District Office's strengths and weaknesses presents a significant problem to Social Security management.

The objective of this model is to demonstrate that a Multiple Goal Programming (MGP) approach is capable of providing management with a tool useful in assessing the operational behavior of the District Office in response to different planning strategies and client performance goals. This includes the identification of the following: a) processing bottlenecks which are delaying the servicing of client requests, b) processing bottlenecks which limit the volume of client requests that can be handled, c) pools of available, yet unused operation resources, d)areas of additional operational resource application, and e) cost implications of providing and upgrading service.

The methodology employs a Multiple Goal Programming approach to District Office planning assessment. Section 2 provides the background to the MGP methodology. Section 3 describes the specific modeling approach employed and the formulation of the general District Office model. A specific example of that formulation process is illustrated in Section 4. The possible uses and implications of the results of the sample model for assessing SSA management planning strategies are discussed in Section 5.

2.0 MULTIPLE GOAL PROGRAMMING

Charnes and Cooper(CHA61) were the first to formulate multiple goal programming (MGP) in order to solve linear programming problems that, because of conflicting constraints, were infeasible. Their formulation used an extension of the familiar linear programming Simplex method. Ijiri(IJI65), in applying MGP to accounting problems developed a generalized inverse approach. A computer model, based on the Simplex approach, was first reported by Lee(LEE72). Representative efforts are Charnes and Cooper on media planning(CHA68) and manpower planning(CHA70), Osteryoung on financial budgeting(OST73), Lee on academic faculty allocation (LEE72), Price on manpower planning(PRI74) and Spivey on national economic policy (SPI70). The use of MGP in information system design and analysis, however, represents a new application of this technique(CHN77).

The MGP formulation employed in this paper is based on the approach taken by Charnes and Cooper(CHA61) and Lee(LEE72). These formulations are extensions of the basic linear (LP) model which can be expressed:

[A] Minimize $Z = C \cdot \beta$

subject to $A \cdot \beta \leq G$

$\beta \geq 0$

where

A is a matrix of technological coefficients

β is a vector of decision variables

C is a vector of cost coefficients

G is a vector of requirements

In order to solve problems of this type, a column vector of slack variables, D, must be added so that the constraints now have the form: $A \cdot \beta + D = G$

The goal of an LP procedure is to optimize the objective function by varying the values of the decision variables. In the solution, the slack vector, D, represents a measure of the discrepancy between the feasible solution and the constraints.

In a MGP formulation, however, it is this discrepancy between the value of the decision variables and the constraints which is the key. The form of the constraint equation remains the same, $A \cdot \beta + D = G$, but the objective function is now to minimize the sum of these discrepancies. Thus, the basic MGP formulation is:

$$[B] \qquad \text{Minimize} \quad \lambda = \sum_{i=1}^{N} Di$$

$$\text{subject to} \quad A \cdot \beta + D \leq G$$
$$\beta \geq 0$$

where

N is the number of goals

In order to minimize the objective function, MGP drives the values of the discrepancies as close to zero as possible by manipulating the values of the decision variables. The result is not an optimal solution like LP but a satisficed solution, one in which the trade-offs between satisfactions and dissatisfactions are minimized. The final values of β represent the levels of allocation of the decision variables to satisfy the stated goals.

To reflect the common objective of minimizing all discrepancies from a goal, formulation [B] must be modified. For a given goal, Gi, MGP allows for variables to represent either a positive discrepancy, Di^+, or a negative discrepancy, Di^- (where both are non-negative and $Di^+ \cdot Di^- = 0$). To insure the integrity of the objective function, MGP requires that the discrepancies in the objective function to be non-negative. Thus, to allow discrepancies to be unconstrained in sign and to be able to characterize both over and under goal achievement, replace Di with $(Di^- - Di^+)$ and formulation [B] becomes:

$$[C] \qquad \text{Minimize} \quad \lambda = \sum_{i=1}^{N} (Di^+ + Di^-)^*$$

$$\text{subject to} \quad A \cdot \beta + D^- - D^+ \leq G$$
$$\beta \geq 0$$

where

D^- is a vector of negative discrepancies

D^+ is a vector of positive discrepancies

This formulation, however, assumes that all discrepancies, even those for over and under performance of the same goal have equal weight. This is usually not the case in many systems. For example, in information systems, it may be more detrimental for actual response time to be over the specified goal than for it to be under it. To handle this asymmetric situation, MGP allows for each discrepancy to be weighted with different

*The objective function minimizes the absolute value of $(Di^- - Di^+)$.

penalties, Pi^+ for excess performance and Pi^- for inadequate performance. Furthermore, MGP provides for ordinal relationships through the use of "preemptive" priority factors. These factors can be applied to any positive or negative discrepancy and are denoted by $F_k i^{\pm}$, where k is the priority level and i is the goal. The discrepancies for more than one goal can be the same priority level. The application of both of these factors constructs a hierarchy of discrepancies, or a goal structure.

The MGP procedure to be employed follows this hierarchy, starting at the highest level, and satisfies all goal discrepancies it can at that level. It then proceeds down the hierarchy, one level at a time, but only after it has completely satisfied the current level. If it cannot completely satisfy a given level it will halt, producing a satisficed solution. If more than one goal discrepancy is at a given level, their relative significance is determined via their associated penalties, $Pi^{\pm}$. The measures of discrepancies for goals at the same priority level must be commensurable, while discrepancy measures across levels need not be. Thus, incorporating priority levels and penalty weightings, the MGP formulation becomes:

$$\text{[D]} \qquad \text{Minimize} \qquad F^+ \cdot P^+ \cdot D^+ + F^- \cdot P^- \cdot D^-$$

$$\text{subject to} \qquad A \cdot \beta + D^- - D^+ \leq G$$

$$\beta \geq 0$$

3.0 FORMULATION

For assessment purposes, a process oriented view of the activities of a District Office is taken. As Figure 3.1 demonstrates, a District Office is assumed to be composed of a collection of Work Stations. These Work Stations are assumed to be a mix or SSA personnel and appropriate technological support.

When a client requests a service from a District Office, it is associated with a particular type of SSA DOWR. For example, in Figure 3.1, client request type 2 is associated with DOWR 2. The processing of a DOWR is mapped to a sequence of Work Stations within the District Office (e.g., the dotted line sequence for DOWR 2). In general, a Work Station (such as Work Station 5) will be in several of the DOWR sequences.

The model assumes that statistics are available which account for each Work Station's processing by DOWR type during a given time period. Current operational data at SSA support this assumption. Several other aspects of Work Station processing are also assumed to be measurable by DOWR type: time spent in processing, time spent waiting to be processed and volume processed.

From the discussion in Section 2, the major determinants in developing an MGP model are the goals: the number and their characterizations. For this DO model, we have direction provided by SSA management. Their four criteria (elapsed time, operational resource levels, volume and cost) can be transformed to goal definitions. Furthermore, the process oriented modeling approach taken in this paper allows for characterization of these criteria in measurable attributes of a District Office's Work Stations. It is assumed that Social Security management's first level of control over operational performance in a District Office is the Work Station: its function, processing rates, manpower and technological requirements and costs.

The constraints of the model corresponding to Social Security management's goals will be discussed first. Several additional constraints pertaining to the feasibility of the model solution are then presented. Table 3.1 provides a summary of the notation to be used in the model formulation to follow.

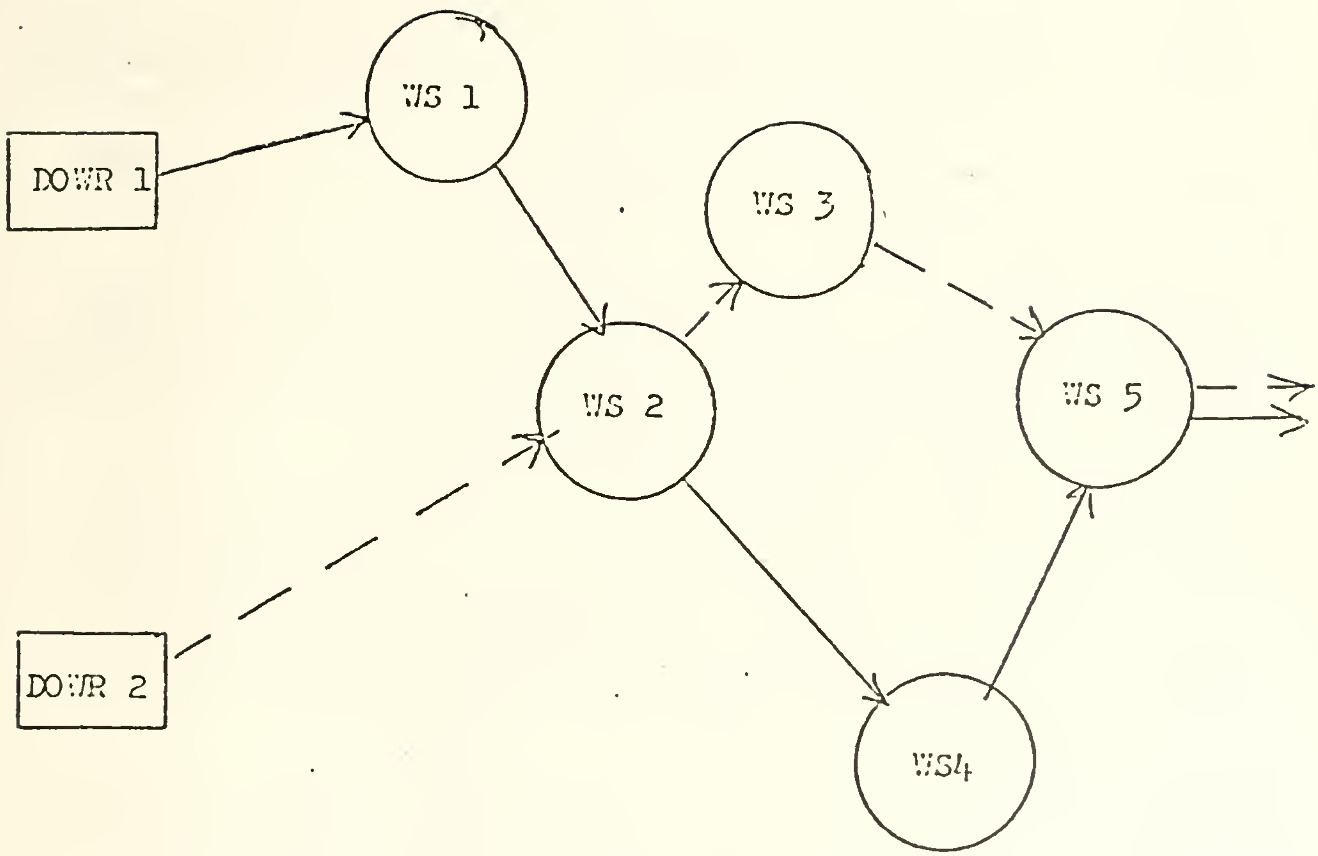

Figure 3.1 Approach to Modeling

Table 3.1 Notation

Identifiers:	
DOWR i	the ith District Office Work Report
WS j	the jth Work Station
Operating Statistics:	
Wij	the number of the DOWR ith processed by the jth Work Station in the given time period
Qij	the mean queueing time for the ith DOWR at the jth Work Station
Pij	the mean processing time for the ith DOWR at the jth Work Station
Rij	the mean service time for the ith DOWR at the jth Work Station .
SSA Specified Goals:	
ET i	the elapsed client service time goals for the ith DOWR
PT j	the processing time per DOWR goal for the jth Work Station
U j	the upper bound on βj modifications
L j	the lower bound on βj modifications
SSA Specified Goal Hierarchy Constructs:	
$Fa^{\pm}$	the priority level applied to the positive/negative discrepancy for the ath goal where a = fn(i,j,k)
$Pa^{\pm}$	the penalty applied to the positive/negative discrepancy for the ath goal where a = fn(i,j,k)
Goal Discrepancies:	
$r_i^{\pm}$	the positive/negative discrepancy for the ET i goals
$t_j^{\pm}$	the positive/negative discrepancy for the PT j goals
$\ell_j^{\pm}$	the positive/negative discrepancy for the L j goals
$u_j^{\pm}$	the positive/negative discrepancy for the U j goal
$e_j^{\pm}$	the positive/negative discrepancy for the unity goals
Derived Measures:	
βj	the decision variable indicating the operating level of the jth Work Station appropriate to satisfy the stated goals structure where βj=1.0 indicates current level satisf
λ^K	total discrepant performance at the kth priority level
$\delta\lambda_j^K$	the marginal contribution to the minimization of λ_j^K due to the modification of the jth Work Station according to β j at the k^{th} priority level

3.1 Total Elapsed Time Constraint

The first constraint characterizes the criterion of total elapsed client service time. It is assumed that the mapping of a DOWR into a sequence of Work Station activities is a linear sequence. Given that Pij is the mean processing time for the jth Work Station and that Qij is the mean queueing time for the jth Work Station, both in service of the ith DOWR, then the total mean service time at the jth Work Station for the ith DOWR is Rij. For a given DOWR, it is assumed that SSA management has specific total elapsed time goal, ETi. This goal is a function of client demand and SSA's projection of the overall processing capabilities of the District Office.

SSA management has many characteristics of each Work Station under its control: its function, manpower level, etc. But from a total elapsed system response time point of view, the total Work Station service time per DOWR has the most direct managerial control implications. Applying Bj to Rij and adding the appropriate discrepancies yields the basic elapsed time constraint:

$$[C1] \quad \sum_{j=1}^{M} Rij \; \beta j \quad + \quad r_i^- \quad - \quad r_i^+ \quad = \quad ETi$$

3.2 Work Station Processing Time Constraint

A major objective of Social Security is to accommodate an increasing client volume at the District Office. But, because of the enormous cost of maintaining, let alone expanding, the current SSA workforce in the future, a stated SSA goal is to service the increased volume with the same manpower level as is currently employed. This implies increased productivity of the current manpower level through increased technological support (computerization, automation, etc.) and/or appropriate reallocation of manpower across Work Stations within the District Office. Neither of these approaches, however, have a direct proportional effect on workload processing capability, i.e., doubling the manpower will not necessarily double the workload serviced. A measure of the overall effect of manpower and technology on the workload at the jth work station is the mean processing time per DOWR. This is the focus of the second set of constraints for the model, comparing the actual time/DOWR to the SSA specified level.

In order to set a processing time performance goal for a given Work Station, WSj, SSA management must consider several factors. Processing time is a function of budgetary limits, manpower and technology capabilities and workload forecasts. The overall cost budget approved for the District Office offers a starting point. This can then be allocated to individual Work Stations, either equally or via a priority scheme. From this, manpower and technological support levels can be established and appropriate personnel and equipment employed. Workload estimations based on projections or historical data provide further input to managements decision.

Several possibilities exist for combining this data into the determination of a performance time goal. In a completely labor-intensive Work Station, total available productive man-hours, in the given time period, divided by expected total workload will yield a target processing time/DOWR. (Note: Productive man-hours implies that allowances for vacation, holidays, sick leave, and other duties have been made). In a completely machine oriented environment, total available machine hours can be substituted for man-hours. (This value may also need to be modified for such occurrences as down-time, repair time, time-sharing, etc.)

In a hybrid, man/machine shop, the average effect of technology support on an individual's processing performance can be estimated and then multiplied by the target manpower level to yield a final measure. And as a final alternative, a target figure can just be set as a result of the performance of other operating Districts Offices, management experience, or management fiat. Whichever approach is used, the goal of mean processing time per DOWR for the jth Work Station in the given time period represented by PTj.

Due to differences in manpower levels and degree of technological support, the number of DOWR's processed in the currently operating District Office environment will vary across all Work Stations. These variations can lead to bottlenecks and delays in the throughput of a particular or all DOWRs. In order to be able to identify such bottlenecks, the quantity of the ith DOWR that was processed at the jth Work Station in the given time period is defined as Wij. It is assumed that this measure can be collected by SSA management.

The measure, Wij, a service rate, is a function of the service time, already defined in Section 3.1 as Rij = Qij + Pij. For constant technological support, Pij is assumed constant with respect to the number of personnel, and thus, Wij = f(Qij). The length that a given DOWR spends in a queue depends on the arrival of the demand, the workload, and the number of parallel servers,(the manpower level.) Thus, Wij is a function of volume and manpower level. Pij, on the other hand, is a function of manpower skill and degree of technological support. Therefore, given a set of Wij's and Pij's for the current operations, the mean processing time at the jth Work Station can be determined by the following expression:

$$\frac{\sum_{i=1}^{N} (Wij \cdot Pij)}{\sum_{i=1}^{N} (Wij)}$$

This expression characterizes behavior at the Work Station level and is, therefore, in line with the assumption that the Work Station is the first unit of management control in the District Office. Thus, applying β_j to the above expression and adding appropriate discrepancies, the Work

Station Processing time constraint is:

$$[C2] \quad \frac{\sum_{i=1}^{N} (Wij \cdot Pij)}{\sum_{i=1}^{N} (Wij)} \beta_j + t_j^- - t_j^+ = PT_j$$

3.3 Feasibility Constraints

In order to complete the formulation, certain logical, physical, and evaluative limitations of information systems must also be taken into account. First, it is assumed that for the short run each Work Station that is present in the current system design must also be present in any future design. Thus, results of this model should not indicate the elimination of any Work/Station, i.e., no βj should equal 0.0. If at a later time, Work Station elimination is a viable alternative, then only those Work Stations than cannot be eliminated would have this additional non-zero constraint.

Second, there may be a physical limitation on the modifications possible for a given WSj. It may not be possible to make the performance of a WSj any longer (shorter), e.g. there is not enough appropriations to hire more personnel. Even if modifications are possible, there may be limits on the degree of change possible, e.g. there is enough appropriations for 50% more personnel. Although there is no guaranteed linear relationship between levels of WSj performance and its effect on overall system performance, a rough limit can be put on the range of β's allowable ($\beta j \leq 1.5$). If such limits exist, it would be counterproductive for this model to produce solutions that violate them. Thus, upper and lower bounds may need to be placed on the latitude given to MGP on determining βj values.

Third, the degree of interdependency that exists in an information system limits the accuracy of evaluative prediction. The ramifications of a change to one Work Station cannot be completely predicted on other Work Stations, such as the elimination of a bottleneck in one Work Station could mean just the transference of the delay to another Work Station. To minimize this 'snowballing' effect, one would like to constrain the MGP procedures to identify only those areas of the current system design that offer the most beneficial results if changed. In other words, by keeping the number of changes to a minimum,(keeping the number of βj's not equal to 1.0 to a minimum,) the complexity and applicability of model results will be improved.

The above conditions have been translated into constraints on the range of βj values that can be produced from the model. These constraints, called feasibility constraints, are described in Table 3.2, The discrepancies from these constraints are automatically added to the objective function at the lowest priority level, i.e., one below that of the lowest SSA specified level.

	Type of Constraint	Reason for Constraint	Form of Constraint	Vector Definition	Discrepancy included in objective function
[C3]	Upper Bound	Restrict Solution to technically feasible	$\beta_j + u_j^- - u_j^+ = U_j$ where $1 \leq U_j$	$(u_1^-, u_2^-, \ldots u_n^-) = U^-$ $(u_1^+, u_2^+, \ldots u_n^+) = U^+$ $(U_1, U_2, \ldots U_n) = U$	u_j^+
[C4]	Lower Bound	Restrict solution to technically feasible: Prevent elimination of an activity	$\beta_j + \ell_j^- - \ell_j^+ = L_j$ where $0 < L_j \leq 1$	$(\ell_1^-, \ell_2^-, \ldots \ell_n^-) = L^-$ $(\ell_1^+, \ell_2^+, \ldots \ell_n^+) = L^+$ $(L_1, L_2, \ldots L_n) = L$	ℓ_j^-
[C5]	Modification Reduction	Minimize number of β_j's $\neq 1.0$	$\beta_j + e_j^- - e_j^+ = 1$	$(e_1^-, e_2^-, \ldots e_n^-) = E$ $(e_1^+, e_2^+, \ldots e_n^+) = E^+$ $(1, 1, \ldots 1) = \bar{1}$	e_j^-, e_j^+

Table 3.2: Feasibility Constraints

3.4 Objective Function

Each of the above constraints contain their associated discrepancies. From these discrepancies, the objective function is formed. For the elapsed time and processing time constraints, both the positive and negative discrepancies (r_i^+, r_i^-, t_j^+, t_j^-) are included in the objective function. Since the left-hand side of these constraints are derived from real or simulated data we must allow for both situations to occur. This also allows SSA management to investigate tradeoffs between individual DOWR elapsed time and Work Station processing time level goals, by providing SSA management with a means to weigh over and under achievement of a goal differently. The discrepancies of the feasibility constraints are identified in Table 3.2

Each of these individual discrepancies can be ranked ordinally by priority level(F_k) and by a penalty within a priority level, (P_k). These discrepancies form an hierarchy of performance criteria against which the actual (or modeled) performance can be evaluated. It is the responsibility of SSA management to provide the specific goal structure. Different preference strategies (i.e., different priorities and penalties) can be easily investigated through this model. The final objective function is:

$$[C6]\ \lambda = \sum_{i=1}^{N} (F^+_{r_i} P^+_{r_i} r^+_i + F^-_{r_i} P^-_{r_i} r^-_i) + \sum_{j=1}^{M} (F^+_{t_j} P^+_{t_j} t^+_j + F^-_{t_j} P^-_{t_j} t^-_j)$$

$$+ \sum_{j=1}^{M} (F^+_{u_j} P^+_{u_j} u^+_j + F^-_{\ell_j} P^-_{\ell_j} \mathcal{L}_j + F^+_{e_j} P^+_{e_j} e^+_j + F^-_{e_j} P^-_{e_j} e^-_j)$$

3.5 Final Formulation

The objective of this model is to provide insight into the performance of a specific District Office system against several design and operating criteria, concurrently. The main criteria in this particular formulation are total elapsed time [C1] and processing time [C2]. Further considerations are given to upper and lover technical bounds ([C3] and [C4]) and to model analysis needs [C5]. Combining [C1] - [C5] with the objective function in [C6] yields the following general formulation:

$$[F1] \quad \lambda = \sum_{i=1}^{N} (F^+_{r_i} P^+_{r_i} r^+_i + F^-_{r_i} P^-_{r_i} r^-_i) + \sum_{j=1}^{M} (F^+_{t_j} P^+_{t_j} t^+_j + F^-_{t_j} P^-_{t_j} t^-_j)$$

$$\sum_{j=1}^{M} (F^+_{u_j} P^+_{u_j} u^+_j + F^-_{\ell_j} P^-_{\ell_j} \ell^-_j + F^+_{e_j} P^+_{e_j} e^+_j + F^-_{e_j} P^-_{e_j} e^-_j)$$

Subject to

For each DOWR i, elapsed time:

$$\sum_{j=1}^{M} Rij \cdot \beta j \qquad + \quad r^-_i \quad - \quad r^+_i \quad = \quad ET\ i$$

For each Work Station, WS j, mean processing time:

$$\frac{\sum_{i=1}^{N} (Wij \cdot Pij)}{\sum_{i=1}^{N} Wij} \qquad \beta j \quad + \quad t^-_j \quad - \quad t^+_j \quad = \quad PT\ j$$

For each Work Station, WS j, feasibility:

$$\beta j + u_j^- - u_j^+ = Uj$$

$$\beta j + \ell_j^- - \ell_j^+ = Lj$$

$$\beta j + e_j^- - e_j^+ = 1$$

4.0 FORMULATION OF SAMPLE MODEL

The model described below is only an example model for the purposes of demonstrating (1) the formulation process, (2) the feasibility of the MGP approach, and (3) the usefulness of model results. The situation is purposely simplistic so that model formulation, not environmental details, are emphasized. Time and resources have not permitted the refinement of the model to handle the idiosyncrasies of DO operations. The basic applicability of this approach, however, is still demonstratable.

The hypothetical District Office processes two types of DOWR's (DOWR 1 and DOWR 2) through three Work Stations (WS 1, WS 2, WS 3). (See Figure 4.1). The specific DOWR request types or Work Stations functions are not important here. Operating statistics (Wij, Qij, Pij, and Rij) are listed in Table 4.1.

To establish the elapsed time constraints, only Rij and ETi are required for the ith DOWR. The target system elapsed time goal is 100 minutes for both DOWR's. Thus, for DOWR 1, the constraint is:

$$[XC1] \quad 60\,\beta 1 + 55\,\beta 2 + 50\,\beta 3 + r_1^- - r_1^+ = 100$$

and for DOWR 2 the associated constraint is:

$$[XC2] \quad 50\,\beta 1 + 85\,\beta 2 + 20\,\beta 3 + r_2^- - r_2^+ = 100.$$

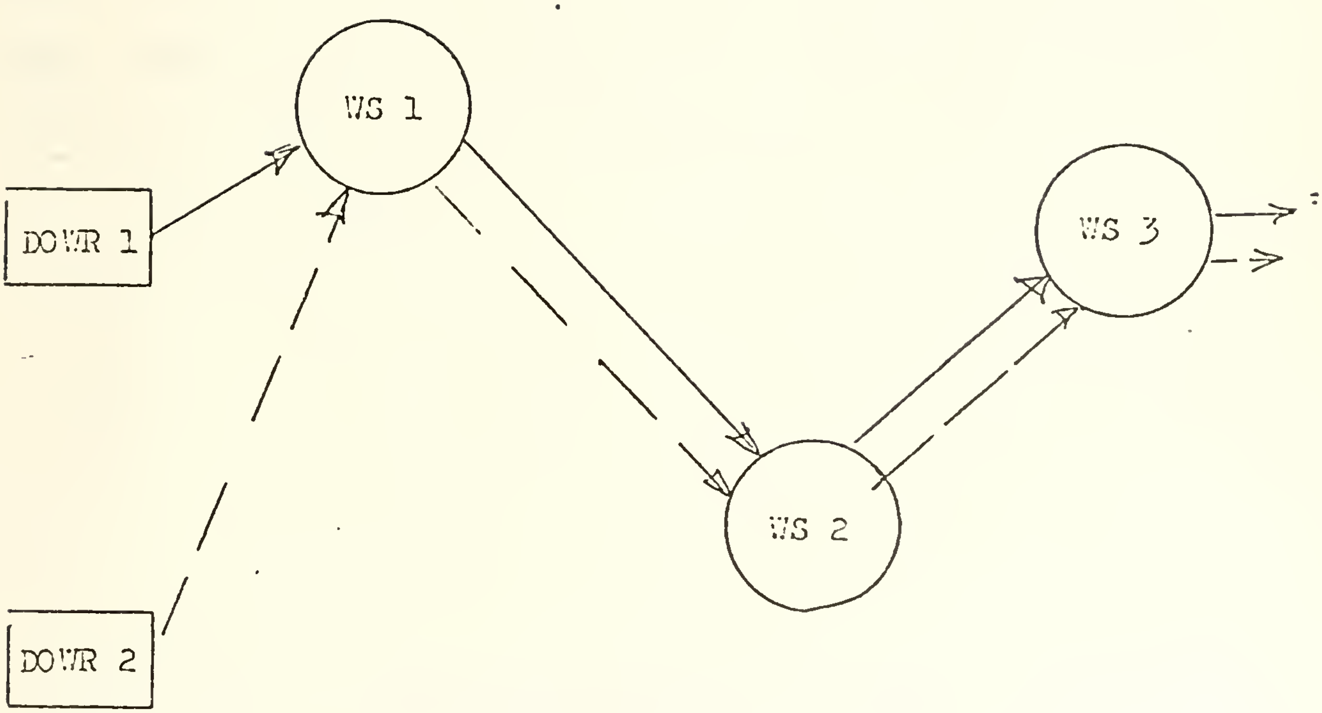

Figure 4.1 Sample District Office

	WS 1	WS 2	WS 3
DOWR 1	300/50/10/60*	200/45/10/55	100/30/20/50
DOWR 2	600/40/10/50	300/65/20/85	200/15/5/20

*Wij/Qij/Pij/Rij

Table 4.1 Operating Statistics
for Sample District Office

Construction of the Work Station processing time constraint for each Work Station is a two step process. First, the current mean processing time is calculated from the set of associated Pij's and Wij's. For the sample model this yields 10.0 for WS 1, 16.0 for WS 2 and 10.0 for WS 3 (all in minutes/DOWR). Second, βj is applied to these values and then set against the SSA determined PTj goals. For the current model the goals are 12.0, 12.0 and 4.0 respectively. Because the elapsed time constraints are in the 100 minute magnitude range, leaving the PTj constraints at their calculated magnitude would bias the model towards the ETi goals. Thus, to equalize the impact of both constraints, the PTj constraints were scaled by a factor of 10. This phenomena occurs in any mathematical programming model where constraints are in different dimensions or magnitudes. Thus, the PTj constraints for WS 1, WS 2 and WS 3 are:

[XC3]	$100\ \beta 1$			$+$	t_1^-	$-$	t_1^+	$=$	120
[XC4]		$160\ \beta 2$		$+$	t_2^-	$-$	t_2^+	$=$	120
[XC5]			$100\ \beta 3$	$+$	t_3^-	$-$	t_3^+	$=$	40

To complete the formulation, upper and lower bounds on β were arbitrarily set to 5.0 and 0.2. To demonstrate the effect of priority levels, three cases of this sample model were formulated. In Case I, the goals of elapsed time and processing time were assigned to the same priority level, the highest, and of equal weight at that level. In Case II, the elapsed time goals were given the highest priority and the processing time goals were given second priority, while in Case III, these positions were reversed. The feasibility constraint, however, were assigned to the lowest priority level in all three cases, but given equal weight at that level. Thus, the final formulation for this sample model is:

[F2] Minimize $= F_a \sum_{i=1}^{2} (r_i^+ + r_i^-) + F_b \sum_{j=1}^{3} (t_j^+ + t_j^-)$

$F_c \sum_{j=1}^{3} (u_j^+ + \ell_j^- + e_j^+ + e_j^-)$

subject to

$$
\begin{array}{rrrrrrrrrrr}
60\ \beta 1 & + & 55\ \beta 2 & + & 50\ \beta 3 & + & r_1^- & - & r_1^+ & = & 100 \\
50\ \beta 1 & + & 85\ \beta 2 & + & 20\ \beta 3 & + & r_2^- & - & r_2^+ & = & 100 \\
100\ \beta 1 & & & & & + & t_1^- & - & t_1^+ & = & 120 \\
 & & 160\ \beta 2 & & & + & t_2^- & - & t_2^+ & = & 120 \\
 & & & & 100\ \beta 3 & + & t_3^- & - & t_3^+ & = & 40 \\
\beta 1 & & & & & + & u_1^- & - & u_1^+ & = & 5.0 \\
 & & \beta 2 & & & + & u_2^- & - & u_2^+ & = & 5.0 \\
 & & & & \beta 3 & + & u_3^- & - & u_3^+ & = & 5.0 \\
\beta 1 & & & & & + & \ell_1^- & - & \ell_1^+ & = & 0.2 \\
 & & \beta 2 & & & + & \ell_2^- & - & \ell_2^+ & = & 0.2 \\
 & & & & \beta 3 & + & \ell_3^- & - & \ell_3^+ & = & 0.2 \\
\beta 1 & & & & & + & e_1^- & - & e_1^+ & = & 1.0 \\
 & & \beta 2 & & & + & e_2^- & - & e_2^+ & = & 1.0 \\
 & & & & \beta 3 & + & e_3^- & - & e_3^+ & = & 1.0
\end{array}
$$

where

For Case I: $F_a = F_1$, $F_b = F_1$, $F_c = F_2$

For Case II: $F_a = F_1$, $F_b = F_2$, $F_c = F_3$

For Case III: $F_a = F_2$, $F_b = F_1$, $F_c = F_3$

5.0 INTERPRETATION

5.1 Discussion

The formulation described in general in Section 3.0 and in specific in Section 4.0, when solved, can provide three sets of measures about the behavior of the District Office in question. They are an evaluation of the current District Office design, the identification of system design alternatives and a first-cut evaluation of these, and other, alternatives. Each set of measures individually provides insight into performance of the District Office, but when viewed collectively, they provide a systematic approach to analysis of District Office behavior and design.

Current Design Evaluation

The first set of measures evaluate the current District Office design with respect to the individual SSA management goals and the entire goal structure. To produce such an evaluation, all the feasibility constraints of the form, $\beta j + e^-_j - e^+_j = 1$, are assigned top priority in the goal hierarchy. This essentially sets the formulation to the current situation by forcing the βj's to equal 1, implying that the current level of all Work Stations equals the required levels. The result is the determination of the positive and negative discrepancies for the SSA management goals.

This evaluation of individual goals is then used to evaluate the global objective function, λ. Since this objective function can be a combination of goals at different priority levels, the result is a vector, one entry per priority level of $\lambda = (\lambda^1, \lambda^2, \lambda^3, \ldots \lambda^k)$ for k priority levels. (Note: For the remainder of this paper all references to the objective function will be denoted by λ, with the understanding that the context can apply to each individual priority level.)

Design Alternative Identification

The second set of measures is the β solution vector. Each βj is associated with a particular Work Station, WS j. It is assumed that SSA management's basic level of control in the District Office is the Work Station.

Thus, the βj values should provide SSA management with insight into controlling these Work Stations for better performance.

Since $\beta j = 1.0$ implies that the Work Station's current operating level is satisfactory for the stated goals, the non-unity cases are the most informative. If $\beta j < 1.0$, then for the elapsed time goals, this implies that the amount of elapsed time spent at WS j is excessive and needs to be reduced. For a processing time constraint, $\beta j < 1.0$ implies that the current operations are inefficient as measured by the current mean processing time and need to be improved by increased manpower or upgraded technology. Thus, for these two constraints $\beta j<1.0$ has a consistent interpretation in that reduced DOWR elapsed time and increased efficiency are compatible aims.

If $\beta j > 1.0$ a different situation is implied. For ET i constraints, WS j is said to have slack time available, i.e. the service time spent at WS j could be longer and still not be over the elapsed time goal for the total DOWR processing. For PT j constraints, $\beta j > 1.0$ implies that operations are too efficient and that there may be excess manpower or technology present at WS j. Again these interpretations are consistent, i.e. decreasing the efficiency of a Work Station can increase the elapsed time at the associated Work Station of the DOWR's that pass through it.

In order to satisfy the objective function, the MGP procedures change all βj's simultaneously. Thus, although a Work Station may contribute to many different SSA goals, the value of βj produced by model solution is with respect to all of these associated goals. The effect of changing the current level of performance for a Work Station on the objective function, i.e. its effect on different priority levels and penalties, has been automatically accounted for. When the goal structure presents a set of conflicting goals, the procedures have to make decisions, based on the specified priorities and penalties, as to which βj's to change so as to satisfy the most important goals. This can cause certain βj's to take on values in order to compensate for the satisfaction of other goals.

Design Alternative Evaluation

The third set of measures evaluate design alternatives, either those indicated by the β solution vector or others suggested by management. These evaluations are based on calculating the marginal contribution of making the specified design change with respect to the further minimization of overall system discrepant performance, λ. Since the closer to 0 λ gets, the better overall performance is, the more negative that the marginal contribution is the better.

This marginal contribution, called $\delta\lambda j$, is derived from characterizing a design change to a Work Station as a value of its associated βj. For example, doubling the manpower level at a Work Station, WSj, could be specified as $\beta j = 0.5$. The procedure is to apply this β_j value to each Rij where $j \neq j'$, producing (Rij) for that WSj. These new (Rij) values will change the evaluation of individual goals, some beneficially and others not. It is the net effect of making this one design change of βj to overall λ that $\delta\lambda j$ measures. If more than one priority level exists, these effects are applied to each associated level k, yielding k, $\delta\lambda_j^k$ measures. A design change is beneficial if the net effect is to further reduce λ, i.e. if $\delta\lambda j < 0$.

The calculation of $\delta\lambda_j$ is made for each Work Station defined for the current system, based on their associated βj value determined above, and for any other design alternatives suggested by management. Based on the value of $\delta\lambda_j$ an ordered list can be assembled, ranging from the most negative value to the most positive value. This list essentially orders the associated design alternatives by the value of their marginal contribution to the minimization of λ, if they were modified according to the value of βj. The most negative value indicates that the associated design alternative has the possibility for the greatest, single reduction in discrepant system performance. The alternative at the other end of the list offers the possibility for the least reduction in λ, possibly increasing it if $\delta\lambda j > 0$. If there are no $\delta\lambda_j$ values less than 0, then it is likely that there is no single design alternative that can reduce λ.

This is very important to the designer/analyst, because every desired design change cannot be made. The costs will probably be prohibitive, sufficient time is probably not available and the ability to isolate and evaluate the effect of a particular change nearly impossible. Thus, the designer only has a finite set of alternatives from which to choose, and it would be of great benefit to have a facility to rank those alternatives in order of their performance improvement possibilities.

5.2 Application to Sample Model

This section present the results of the sample model and discusses their interpretation in light of the three sets of measures described above. It should be emphasized that the model employed is simplistic for the purposes of demonstration and understanding.

Current Design Evaluation

For the specific model formulated in Section 4, all βj's were set to 1.0 and the formulation was solved via a computer program version of MGP. The individual discrepancies are listed in Table 5.1. It should be noted that these discrepancies do not change across the three different cases analyzed. The values of λ^k, however, did change and are listed in Table 5.2

If the actual performance in the system, the District Office, is greater than that of the goal, then the positive discrepancies have non-zero values. For example, in goal ET 1, with the actual system elapsed time for DOWR 1 being 165 minutes, $r_i^+ = 65.0$. For goal PT 3, the actual processing time at WS 3 was 100 time units, while the target processing time was only 40, leaving a positive discrepancy of $t_3^+ = 60.0$. This implies that WS 3 is processing DOWR's too slowly. The converse situation, actual performance less than goal performance, yields a non-zero negative discrepancy. As an example, in goal PT 2, the goal level is greater than the actual level, and $t_2^- = 20.0$.

Design Alternative Identification

The results of the computer solution of each of the three cases are presented in Table 5.3. In Case I, all three Work Stations are operating too slowly and need to increase manpower and/or technological support as indicated by all three βj less than one. For Case II, with the ET i goals having top priority, all three Work Stations were still processing too slowly, but with a shift in degree between WS 2 and WS 3. For Case III, however, with the PT j goals in top priority, WS 1 has an excess of productivity (i.e. it is operating too fast), which can be possibly shifted to WS 2 and/or WS 3 which need processing help, indicated by their less than

GOAL	DISCREPANCY	VALUE
ET 1	r_1^+	65.0
	r_1^-	0.0
ET 2	r_2^+	55.0
	r_2^-	0.0
PT 1	t_1^+	40.0
	t_1^-	0.0
PT 2	t_2^+	0.0
	t_2^-	20.0
PT 3	t_3^+	60.0
	t_3^-	0.0

Table 5.1 Current Design Evaluation of Sample Model Discrepancies

	λ^1	λ^2	λ^3
Case I	59.45	15.60	N/A
Case II	10.00	62.5	15.61
Case III	0.0	31.75	16.05

Table 5.2 Current Design Evaluation of Sample Model: λ^k values

	Case I	Case II	Case III
β_1	.64	.74	1.2
β_2	.75	.64	.75
β_3	.40	.40	.40
Priority Level			
F1			
$\delta\lambda_1$	-3.5	-28.6	-20.0
$\delta\lambda_2$	-75.0	-50.4	-40.0
$\delta\lambda_3$	-102.0	-42.0	-60.0
Priority Level			
F2			
$\delta\lambda_1$	---	+26.0	+22.0
$\delta\lambda_2$	---	-22.4	-35.0
$\delta\lambda_3$	---	-60.0	-42.0

Table 5.3 Design Alternative Identification and Evaluation for a Sample Model

unity βj values.

Design Alternative Identification

Each of the sets of βj values produced for each case were further processed by $\delta\lambda j$ analysis. The results of this analysis are also presented in Table 5.3. Each case demonstrates a different SSA management decision situation.

For Case I, because all goals were at the same priority level (and of equal weight), the impact on an ET i constraint of a βj change in operational behavior for a given WS j must be weighed against not only other ET i constraints, but also against the PT j constraint for that WS j. Although it is not an absolute measure, it is easily seen that $\delta\lambda_j$ is not in the same magnitude range as $\delta\lambda_2$ and $\delta\lambda_3$. So the choice is left between WS2 and WS 3 with WS 3 having the slight $\delta\lambda j$ edge (-102 vs. -75). An interesting point is that all three $\delta\lambda j$ values are negative, indicating that the associated βj change for any WS j would be beneficial.

For Cases II and III, the calculation of $\delta\lambda j$ had to be divided into $\delta\lambda j^{F1}$ for priority level F1 and into $\delta\lambda j^{F2}$ for priority level F2. A fundamental assumption of preemptive levels is that one unit of a measure in a higher priority level is immeasurably more important than one unit of a measure in a lower priority level. In the sample model, this produces some interesting management decision situations.

For Case II, WS 2 has a slight edge at priority F1, while at F2, WS 3 has a definite beneficial advantage. Conflicts arise, however, when comparing the effects between levels. For WS 1, the same change which produces a beneficial (-28.6) effect at F1, produces a worsening effect (+26.0) at F2. If such a change to WS 1 is contemplated, SSA management must decide if the units sacrificed at F2 are worth the improvement at F1.

Between WS 2 and WS 3 an interesting battle exists. The $\beta 2$ change that produces the lowest $\delta\lambda j$ value at F1 also produces a beneficial, although not the lowest, $\delta\lambda j$ value at F2. The $\beta 3$ change produces the reverse situation, beneficial values at both F1 and F2, with the lowest value at F2. The question is whether the 7.6 advantage that WS 2 has over WS 3 at F1 is worth the 37.6 disadvantage at F2. The solution is in the domain of SSA management tradeoff decisions.

The crux of this analysis is not in comparing the absolute differences between $\delta\lambda j$'s. Although the conflict in WS 1 between F1 and F2 can be seen from the initial formulation, the tradeoff dilemma between WS 2 and WS 3 is not obvious, even in this simple case. Thus, the design alternative evaluation not only provides insights into conflicting operational behavior, but also signal areas where further investigation and/or hard management decisions need to be made. It must be emphasized again that the actual design changes are management's responsibility.

And finally, in Case III, the processing time goals have top priority. As Table 5.3 shows, the same conflict that exists in Case II over WS 1 still exists in Case III, even though WS 1 is now to be modified in the opposite direction ($\beta 1 = 1.2$ vs. $\beta 1 = .74$). WS 2 and WS 3 modifications, however, are less conflicting, with $\delta\lambda_3$ being the lowest in both F1 and F2. Over all cases, WS 3 appears to be the most critical Work Station for the DO.

6.0 SUMMARY

This paper has discussed the formulation of an MGP model of an SSA District Office. The operating characteristics of a DO have been related to the satisfaction of SSA performance criteria of total elapsed client service time, operational resource levels, workload volume and costs through a series of goal constraints. By use of a simple, example District Office, the formulation, solution and interpretation of the MGP model has been demonstrated.

This demonstration, however, is only an initial step. Larger scale District Office models should be investigated to test the consistency and applicability of the basic model formulated in this paper. Statistics from an operational or modeled District Office should also be collected in order to validate the model. Other SSA management goals, or further refinements of current criteria, should be considered in an expanded formulation.

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